Future Directions in Stratigraphy

Special meeting of the
International Commission on Stratigraphy (ICS)

Urbino, Italy, 14-16 June 2002

Summary and Report

Outline

Acknowledgements

The ICS thanks Stan Finney (ICS vice-chair) for organizing the meeting, and is very grateful to Prof. Rodolpho Coccioni and Dr. Simone Galeotti of the University of Urbino for hosting this conference and associated scientific and social program. Financial support the Urbino conference logistics was provided by the IUGS, and travel support for several participants was from a special grant from ICSU.

Executive Summary

The special planning meeting of the International Commission on Stratigraphy (ICS) in Urbino, Italy on 'Future Directions in Stratigraphy' on 14-16 June 2002 has been overwhelmingly successful. A few highlights of this first-ever assembly of all ICS voting members are given below.

ICS Mission

The Commission is the primary body for facilitation of international communication and scientific cooperation in stratigraphy, defined in the broad sense of multidisciplinary activities directed towards better understanding of Earth history. The ICS needs to excite the next generation with new tools, high-resolution event correlation on a global scale, and other projects with relevance to public concerns and imagination.

To accomplish this mission, the Commission establishes several **strategic goals**, including:

1. **Completion of standards**
   a. A total commitment by the stratigraphic subcommissions to assign boundary stratotypes for the entire Phanerozoic by the year 2008.
   b. Revitalisation of a Subcommission on Quaternary Stratigraphy scientifically linked with INQUA to propose major subdivisions of the Pleistocene and the base of the Holocene.
2. **Enhanced visibility and publications**
   a. More effective and broader publication and distribution of the scientific accomplishments of ICS, particularly with respect to new stratigraphic standards, time scale, color codes, stratigraphic guidelines and nomenclature.
   b. A business-like approach to creation and marketing of important stratigraphic products such as geologic time scale posters, boundary stratotype standard brochures, international stratigraphic guide, stratigraphic teaching modules on CD, and major stratigraphic datasets.
   c. A stratigraphic scientific journal sponsored by ICS, which would receive a portion of the income. One possibility is an upgraded and expanded *Newsletter in Stratigraphy*.
   d. An electronic stratigraphic 'journal' with full-fledged articles and databases to link and complement the printed journal of ICS.
   e. A theme-oriented popular stratigraphic journal directed toward understanding new stratigraphic concepts and events. This journal would have beautiful front-page covers, full color images, and general-geology level of review articles on exciting topics.
   f. International stratigraphic prizes (*Hedberg* and *Steno*) to be awarded every 4th year coincident with the IGC.
   g. Potential creation of the 'International Association of Stratigraphic Geologists' (IASG) maintaining close ties with IUGS and preserving a major part of the present Subcommission structure with unique expertise for major Periods of the stratigraphic column.
3. Coordination of comprehensive stratigraphic databases (e.g., CHRONOS system)
4. An Urbino-style all-membership planning meeting will be held every second year.

INTRODUCTION and OVERVIEW OF ICS FUTURE

1. Welcome by Chair of Faculty at Campus Scientifico dell' Università, Urbino

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2. Purpose of Conference

Stan Finney (2nd Vice-Chair of ICS and conference chair)

This ***Future Directions in Stratigraphy*** is an initiative set up by the ICS Executive to increase internal cooperation and plan future ICS activities.

Until now, each Subcommission has worked in isolation. Only the voting for GSSPs crossed boundaries. ICS has never had an intensive meeting of all its members.

The past emphasis of ICS has been on nailing the international geological time scale with GSSPs, and this effort will be completed in 2008.

This workshop has two main goals – summarize the current status, and prepare for the future.

The future mission of ICS will be presented in a public meeting hosted by ICS in Florence in 2004.

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3. IUGS Overview

Werner Janoschek (IUGS Secretary General and Treasurer, ***sg.iugs@cc.geolba.ac.at***)

ICS is the largest and most important IUGS commission. Our strategic planning for 6 years ahead is much commended and appreciated.

IUGS started in 1961, under International Council of Scientific Unions (ICSU). IUGS is a non-governmental, non-political, non-profit scientific organization with 115 National members, 17 Associate members and 37 Affiliates. The IUGS Council meets every four years at the International Geological Congress (IGC). The Congress an independent body, much older than IUGS, but IUGS is the main sponsor and the two bodies are planned to merge in the future. UNESCO is an active partner with IGCP (International Geological Cooperation Program).

There are 8 Commissions in IUGS, of which ICS is the largest expert group in IUGS and the flagship commission. As a result, ICS has five to ten times more funding from IUGS than any other commission.

The other IUGS commissions are environmental geology (COGEOENVIRONMENT), Global Sedimentary Geology, History of Geological Sciences, Igneous and Metamorphic Petrogenesis, Systematics in Petrography, Tectonics, information management (COGEOINFO), and education (COGEOED). There are also IUGS working groups for geochronological decay constants, global geosites, continental geochemical baselines, fossil fuels and public affairs. New IUGS initiatives are geoindicators and medical geology (both from COGEOENVIRONMENT).

IUGS is considering an ***International Year of Planet Earth*** for 2004.

More information on IUGS, publications, and commission activities are at the IUGS website: ***www.iugs.org***.

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4. Florence 2004 International Geological Congress

Leo Boriani (new President of 32nd IGC)

Copies of the IGC First Circular (just printed) can be requested from ***casaitalia@geo.unifi.it***, or the IGC website. The Second Circular will be March 2003.

The IGC returns to Italy after 123 years). The initial IGC was in Paris in 1878, the second in 1881 in Bologna and already came out of needs for standards in stratigraphy.

The Florence 2004 IGC will be Aug. 21–28 (2 days shorter than the previous one in Rio de Janeiro, due to having no weekend break). The program includes Special Symposia (only invited speakers), plenary lectures (about twelve, before lunch), general sessions, poster sessions with free beer, field trips (nearly 100 different ones are proposed in the first circular), etc. Abstract deadline is Oct. 2003, and all session planning will be handled electronically to avoid confusion.

Registration is about 450 Euro, with 20 Euro of each registration will go to IUGS and to commissions.

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5. Present and Future Directions in ICS

Felix Gradstein (Chair of ICS)

ICS is a body of expert stratigraphers founded for the purpose of promoting and coordinating long-term international cooperation and of establishing and maintaining standards in stratigraphy.

The scientific activities shall be carried out through projects or meetings arranged in collaboration with IUGS-affiliated organizations, IUGS-joint programs, non-governmental bodies and inter-governmental bodies. Some commission work will always exist and be part of our mandate, but we can with own funds start to encourage IGCP style projects on specific new and socially relevant topics.

Principal objectives (proposed new missions are in **bold**)

(a) the establishment and publication of a standard global stratigraphic time scale and the preparation and publication of global correlation charts, with explanatory notes,

(b) the compilation and maintenance of a stratigraphic database center for the global earth sciences.

(c) the unification of regional chronostratigraphic nomenclature by organizing and documenting stratigraphic units on a global database,

(d) the promotion of education in stratigraphic methods, and the dissemination of stratigraphic knowledge,

(e) the evaluation of new stratigraphic methods and their integration into a multidisciplinary stratigraphy, *and*

(f) the definition of principles of stratigraphic classification, terminology and procedure, and their publication in guides and glossaries.

ICS Strengths and Weaknesses

ICS is academically very strong but lacks a good business plan. Many items like time scale, strat guide, guidebooks, strat teaching material on CD , strat lexicons etc. are items that can be sold with small profit.

Strengths

- Solid academic tradition and quality
- Best experts/ international representation
- Good support from IUGS
- *Improved* information/data communication
- Good progress with standardization *(GSSPs + Stratigraphic Chart)*
- Leadership in CHRONOS database initiative
- Good links to national Geological Surveys
- Good support from successive IGCs
- Good 'stratigraphic' workshops/conferences

Weaknesses

- Lacks a publishing face
- No high-profile (actual) scientific visibility
- Information + data can be difficult to find
- Stratigraphic standardization has been the all-absorbing task
- Some disagreement in stratigraphic guidelines
- Little visibility with industry *(e.g., seq. strat. and time scale)*
- Generation gap *(no under 40 voting members)*
- No teaching modules *(stratigraphy has low esteem in academic curriculum)*
- Non-business mentality; ignores funding potential

Scientific Challenge and Future Mission

- Complete stratigraphic standardization by 2008
- Top-notch teaching modules in all aspects of stratigraphy
- Develop geological process oriented stratigraphy

  High-resolution global change as seen through the eyes of dynamic stratigraphy, i.e. geological process oriented stratigraphy is an exciting and socially responsible challenge . In this human era, global changes and global environmental challenges are ever more pressing issues. Stratigraphy plays an exciting role in this, since its fossil record can often be unraveled to a level of detail and accuracy in correlation that allows great insight into the dynamic forces that drive global changes. It is this geological process oriented stratigraphy that is the most exciting and meaningful as new mandate. It will greatly improve the resolution in the Geological Time Scale.

Some Potential Future Scientific Initiatives

- Specific high-profile stratigraphic projects (like IGCP)
- Limited role as global stratigraphic watchdog/caretaker
- Active unified website (SIS initiative) for all information and data
- Create principal publication medium (*Chronos* journal)
- Relational (ORACLE-type) stratigraphic databases (expanded CHRONOS database initiative)
- International stratigraphic prize (***Steno*** and ***Hedberg*** prizes)

Stratigraphic Information Services

New program under ICS with the following components:

- Geological Time Scale Information
    - *Geological time scale subdivisions and GSSPs*
    - *Age dates, Orbital cycles, and Absolute time scale*
    - *Stable isotope and Geochemical curves*
    - *Magnetic and Sequence chronology*
- Stratigraphic Database Center and Links (See below for details on this CHRONOS initiative)
    - *Biostratigraphic and evolutionary databases*
    - *Integrated Stratigraphic Network and links*
    - *Stratigraphic tools (statistics, temporal-spatial GIS-type displays, paleogeography)*
- Stratigraphic Standards
    - *Stratigraphic Code on-line, with short-term working groups for revisions as required*
    - *Geochronology and other standards*
- Geohistory Education Site and Links
    - *What is the geological time scale*
    - *Adventures in geo-time (with links)*
    - *New discoveries and concepts*
    - *Stratigraphic applications and methods*

Future ICS Organization Suggestions

Some recent changes:

- *New Statutes approved – Single vice-chair, 'Task group' instead of 'Working group'*
- *Quaternary merged with Neogene into joint subcommission after discussions with INQUA and dual-commission 'science planning' meeting in Utrecht*
- *Geochronology and Gondwana subcommissions were dissolved*
- *Stratigraphic Information Services created as a task-oriented group (not a subcommission)*
- *Task group formed to compile radiometric age database*

Post-2008 possibilities:

- More compact subcommission structure *(in contrast to current 14 subcommissions)*
  - Pre-Cambrian, Paleozoic, Mesozoic, and Cenozoic subcommissions
  - + IGCP style projects on actual fundable topics
- Central coordinating office (= improves national contacts)
- Adopt science business model (AGI, AGU, IAMG, SEPM, etc.)
- Membership with small fee and free top-notch stratigraphic. journal
- Closely affiliated with IUGS
- Publicize and sell products, such as:
  - *stratigraphic guide, CD's with standards,*
  - *time scale cards and charts,*
  - *books, journal (s),*
  - *teaching compendia, slide series, stratigraphic highway guide books,*
  - *index fossil collections, etc.*
- Rename as…. *International Association for Stratigraphic Geology*…?

The *Association* concept

IAMG (Internat. Assoc. Mathematical Geology), AGU (Amer. Geophys. Union), SEPM and other associations are successful professional organizations with good funding of their own making.

ICS will appoint a small task group to formulate a plan to look into becoming an association after 2008 with a publishing house, own journal with electronic features (3D, color, dynamic) such as stratcube and 4 D simulations and dynamic stratigraphy views, paying members, student fees, joint conferences with other associations, keynote lectures at symposia , credit-card payment for members, links to amateur collector organizations, national surveys, field meetings, etc.

Members must feel they belong to something!!!!

Time Frame for Future ICS Directions

- Urbino 2002 Workshop
  - *Provide guidelines and objectives*
  - *Prepare planning guide and template*
- Florence 2004 Workshop
  - *Present details of GSSP and organizational progress*
  - *Discuss specific plans for implementation*

- ICS 2nd workshop 2006 (Vienna?), or in 2007/2008
    - *ICS re-news and re-organizes, including*
    - *ICS adopts new name*
    - *New and improved scientific objectives*
    - *New business mode*

CURRENT STATUS OF ICS IN FULFILLING OBJECTIVES

1. Summary of ICS Standards – International Stratigraphic Chart and GSSPs

Jim Ogg (Secretary General of ICS)

The ICS website (***www.stratigraphy.org***) contains the following compilations:

- Table of all ratified GSSPs. About half of these GSSP entries now link to dedicated pages with standardized-format location maps, stratigraphic sections, and correlation markers. More information and photographs of ratified GSSPs are posted on some of the individual subcommission websites (e.g., suite on the Neogene Subcommission website).
- The status of potential correlation levels and stratigraphic points for the remaining geological stages. This table is being constantly updated.
- The associated International Stratigraphic Chart (PDF formats) with color schemes in both 'Paris' (Commission of the Geological Map of the World) or the 'USGS' (U.S. Geological Survey coordinated with other North American surveys). A table of the official colors (CMY or RGB) for each version can also be downloaded.

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2. Reports of Individual Subcommissions

The detailed 2001 Annual Report of each subcommission, plus an updated status of GSSPs for each period are posted on the ICS website (***www.stratigraphy.org***). Only selected highlights of the Subcommission reports are given below.

a. Terminal Proterozoic

Andrew Knoll could not attend, but the 2001 report indicated that final voting was underway for the correlation criteria and GSSP location. The most contentious issue is the eventual name for the terminal-Proterozoic period.

b. Cambrian *(by John Shergold)*

The philosophy of the Cambrian subcommission was to begin with a clean slate, rather than try to blend competing regional stage concepts. First, they identified biohorizons that have widespread correlation potential. Second, they identified the preferred location for each GSSP. Third, they assigned a new name for the series and stage.

The subcommission expects to complete subdivision of the upper and middle Cambrian by 2003. The lower Cambrian will be the most difficult. There is also a chronostratigraphy working group.

c. Ordovician *(by Stan Finney)*

The Ordovician was in terrible confusion with constantly changing regional zonations and stage names. For example, a 2001 paper in GSA Bulletin on Appalachian tectonics mixed British, Australian and North American regional stage names. The 'traditional' UK subdivisions were not

useful on a global scale, therefore the Subcommission voted to abandon these UK-based units and names in 1995.

Therefore, this group has the same philosophy as the Cambrian – identify correlation levels and GSSP placements, then assign new names (unless an existing regional stage name closely corresponds to the new GSSP-delimited unit). As a result, some stages currently have a basal GSSP, but await assignment of the stage name (with ICS voting required by statutes) pending decision on their upper limits. Each paleoplate has its own set of series and zones, which now are to be correlated to a set of *Global Stages* and key faunal markers, keeping Lower, Middle and Upper as the names of the *Global Series*.

d. Silurian *(by Jia-yu Rong)*

The placements of a full suite of Silurian GSSPs in the early 1980's were heavily based on discontinuities in British lithostratigraphy, rather than consideration of widespread correlation potential. Some GSSP sections even lack biostratigraphic control (see GSSP summary on the ICS website). For example, the series-level base-Wenlock GSSP is within a hiatus spanning three graptolite zones, and the base-Ludlow GSSP has no index fossils. Only the base-Silurian GSSP at Dob's Lin in Scotland seems to be within a continuous succession, but the cited placement near the lowest graptolite occurrence of *Parakidograptus acuminatus* sensu stricto is incorrect and a placement near the lowest graptolite occurrence of *Akidograptus ascensus* would enable better global correlation..

Therefore, the Silurian Subcommission must now review some of these lithostratigraphy-based GSSPs. A vote within the subcommission indicated that the priority GSSPs for review are the base-Silurian (a working group led by Mike Melchin) and the base-Wenlock (led by David Loydell). GSSPs must be changed only with care and rigor to provide long-term stability.

e. Devonian ***(by Pierre Bultynck)***

The Devonian is fully pinned by stage-level GSSPs. Full details on the GSSPs and fossil groups important for stage definition are recently published (2000 and 2002) in the *Courier Forshunginstitut Senckenberg* (volumes 220 and 225).

However, some stages are over 10 myr in duration and require standardized substage-level definitions for global usage. Substages (Upper, Middle and Lower terminology) are being developed for the Famennian, Frasnian, Givetian and Emsian, and will be completed by 2004. These will not be GSSP-based definitions, but correlation charts for neritic and pelagic facies that include the recommended substage terminology. The substages will be associated with conodont and sea-level events.

f. Carboniferous ***(by Richard Lane, with contribution by Phil Heckel)***
(Heckel's flight was delayed and missed the overseas continuation)

The Carboniferous was one of the first periods to be established, but is the least advanced with GSSP subdivisions. For the past 25 years, the Carboniferous Subcommission has been trying to meld the independent European, North American and Russian subdivisions and nomenclature. The Carboniferous is now formally divided into Mississippian and Pennsylvanian subsystems, and it is probable that the component series and stage units will use Russian names. A base-Visean GSSP (=base of middle Mississippian series) in China using *Eoparastaffella simplex* foraminifer is close to agreement. The Subcommission will meet a 2008 goal of establishing all GSSPs.

g. Permian ***(by Bruce Wardlaw)***

The stages of the Middle Permian were approved in 2001. The base-Lopingian GSSP (= base of upper Permian series) is undergoing a vote in the Subcommission. A Volgian regional working group is active in understanding how the traditional Russian upper-Permian stages (Tatarian, etc.) correlate to the international stages (Changhsingian, Wuchiapingian). A Russian team will spend two months with the Permian Research Institute (Boise, Idaho, USA) to decide on placement of lower Permian stage GSSPs. All Permian GSSPs, except the base-Kungurian which has a severe regression, will be established by the Florence 2004 IGC.

h. Triassic ***(written report was submitted by Michael Orchard)***

No intra-Triassic GSSPs are yet assigned, but the Triassic working groups are actively striving to meet an ambitious schedule. Decisions on Middle Triassic GSSPs (base-Anisian will probably be in Romania and base-Ladinian in either Hungary or Italy) will be made by 2003. A base-Carnian GSSP and perhaps base-Norian GSSP will probably be chosen in 2004. The base-Olenekian and base-Rhaetian GSSPs are more difficult, but the goal is completion by 2005.

i. Jurassic ***(by Nicol Morton)***

Arkell (1951) standardized most Jurassic stages as clusters of ammonite zones, and the Subcommission has generally followed these ammonite criteria. Most GSSPs will be decided in the next four years. The Jurassic symposium in Sicily (Sept., 2002) is expected to decide on base-Pliensbachian and base-Callovian GSSP placements. One problem is that publication of the details of a fossil-rich GSSP in Germany may lead to destruction by amateur collectors. The important base-Jurassic GSSP has potential sections in SW England, Peru and western Canada). The base-Oxfordian and base-Kimmeridgian definitions are subject to obtaining reliable Boreal-Tethyan correlations, which indicate approximate 0.5 myr offsets in the different traditional placements among regions. The base-Bathonian once had a GSSP proposal, but the details of the section need to be confirmed. The base-Toarcian GSSP currently has no candidate sections, and the uppermost Jurassic stage of Tithonian is mainly useful in the Tethyan region. Most GSSPs will be sorted out in the next

The Jurassic Subcommission has established thematic task groups on geosites (conservation of key outcrops), sequence stratigraphy, paleo-biogeography, relations with amateur collectors, and other items. Paleoclimate and tectonics during the Jurassic are future themes.

j. Cretaceous ***(by Peter Rawson)***

The Subcommission has approximately 130 members working in 13 task groups for the 12 stages (the odd task group is for Lower Cretaceous ammonites). Possible GSSPs for all stages and substages were published after an intensive meeting in Brussels in 1995. Base-Maastrichtian and base-Cenomanian GSSPs are ratified, and base-Turonian will be decided in 2002. The remainder of the Late Cretaceous suite will be finished soon, but the Lower Cretaceous is hindered by pronounced bio-provincialism. The base-Aptian was proposed to coincide with a magnetic reversal (a break with tradition), which sparked re-investigation by French ammonite paleontologists.

Defining the base of the Cretaceous (perhaps the base of the traditional Berriasian stage) has proved the most difficult, even after 30 years of focused conferences with passionate discussions. Geopolitics and tradition, in addition to Jurassic provincialism, have been the main stumbling blocks. Only 7 people responded to an early-2002 call to reform a working group.

k. Paleogene ***(by Hans-Peter Luterbacher)***

The base-Cretaceous is placed at the iridium anomaly at the boundary clay in El Kef, Tunisia, and there is a Paleo-3 special issue on the boundary in this region. Base-Thanetian and base-Selandian of the Paleocene have good potential sections. The base-Eocene GSSP near Luxor, Egypt, is undergoing a subcommission vote and is proposed to coincide with the base of a pronounced global carbon-isotope anomaly. Progress in assigning GSSPs within the Eocene has been slow, except for the base-Lutian with a candidate section in the Betics of Spain. A base-Chattian (mid-Oligocene) proposal is coming in 2002. Most GSSPs within the Paleogene should be established before the Florence 2004 IGC.

l. Neogene ***(by Domenico Rio, reading summary submitted by Neogene Subcommission)***

GSSPs within the Miocene are progressing well, with a prime criteria for GSSPs being suitability for high-resolution cycle-stratigraphy. The base-Tortonian GSSP (placed near Ancona coinciding with lowest occurrence of discoaster *kugleri*) is expected in 2003, and base-Serravillian in 2004. GSSPs in the lower Miocene (base-Langhian and base-Burdigalian) is not expected prior to 2006 due to difficulties in finding land outcrops that can be tied into the cycle-stratigraphy developed in deep-sea sections (e.g., Ceara Rise of South Atlantic).

The Neogene System encompasses the Miocene through the Holocene. Formal subdivision of the Pleistocene series should now proceed with the new agreement to include this aspect of the INQUA Commission on Stratigraphy (which had been dormant) with the Neogene effort. A joint Pleistocene group that is co-chaired by Gibbard (INQUA-Strat. Comm. secretary) and Castadori (ICS-Neogene secretary) will prepare GSSPs or GSSAs to formalize the main divisions (see the following Quaternary presentation).

m. Quaternary stratigraphic subdivisions ***(by Philip Gibbard)***

The Quaternary is traditionally considered to be the interval of oscillating climatic extremes (glacial and interglacial episodes) that was initiated at about 2.5 Ma. Marine oxygen isotopes provide a suite of well-defined ‘stages’ that can be partially correlated to continental glacial surges (regional ‘stages’ of Eemian, Würm, Illinoisian, etc.) and anthropologic trends (‘trace fossil’-based ‘stages’ such as Paleolithic, etc.). Essentially, the sets of Quaternary ‘stages’ are equivalent to ‘zones’ of isotopic or biostratigraphic chronostratigraphy within the rest of the Phanerozoic systems, but Quaternary usage of the term ‘stage’ is now too entrenched to be revised. Therefore, to avoid confusion, the broad subdivisions of the Pleistocene should be called ‘subseries’, rather than ‘stages’.

The base of the Middle Pleistocene ‘subseries’ is generally placed at the Brunhes-Matayama magnetic reversal boundary at 780 ka, the base of the Middle Pleistocene ‘subseries’ is the base of the Eemian interglacial stage (= base of marine isotope stage 5e) at 126 ka, and the base of the Holocene is commonly assigned as exactly 10,000 Carbon-14 years (= 11.5 ka calendar years BP) at the end of the Younger Dryas cold spell. Physical GSSPs to coincide with these chronologic definitions would be most convenient in an ice core (base of Holocene, unless a GSSA-concept is used), a level in a sediment core under the Netherlands (base of Eemian ‘stage’), and perhaps the magnetic reversal position in Icelandic volcanic flows (base of Brunhes magnetic zone).

A task group was established to prepare an organization and a science plan (with deadlines) to formalize these divisions. Philip Gibbard, the INQUA representative, assured ICS that standardization of the Pleistocene is more a matter of mis-communication between ICS and INQUA than of a disagreement among Quaternary workers.

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3. Stratigraphic classification items

a. Stratigraphic Classification Subcommission *(by Maria-Bianca Cita)*

This Subcommission was established in Algers in 1952. A 20-year effort under Hedberg produced the first International Stratigraphic Guide. Amos Salvador supervised a second edition (1994), followed by an Abridged Guide (2000) published in *Episodes*. Preparation of these Guides involved nearly 100 circulars (3000 pages). More details are on the subcommission's new website (***www.geocities.com/issc_arg/, although items on this site seem to be occasionally overlain by GeoCities advertisements),*** and the Abridged Guide is reproduced on the ICS website (*www.stratigraphy.org*).

The Subcommission has been discussing standardizing concepts and terminology in sequence stratigraphy (16-member working group for past 6 years) and cycle stratigraphy (3-member group of Schwarzacher, Hilgen and Strasser). The AAPG Hedberg conference on sequence stratigraphy (Dallas, 2001) indicated that this aspect of stratigraphy is still an arena of debated concepts that can not even agree on the definition of 'sequence'. The cycle stratigraphy group has submitted a suite of recommendations. Both of these working groups will be disbanded in 2002.

The future directions of the Subcommission will include:

(1) Definitions, concepts and procedures in cycle stratigraphy, magnetic stratigraphy, ice core stratigraphy and other new stratigraphic methods.

(2) Application of concepts and procedure to other areas of geoscience (e.g., igneous mapping, and petrologists who often don't follow the Guides), to other nations and in geoscience education

(3) Revisiting lithostratigraphy, including improved and on-line lexicons (catalogues of national lithostratigraphic units) and discontinuity-bound units (sequences and volcanic units).

b. Russian Stratigraphic Guide (by Yury Gladenkov)

The Russian Stratigraphic Code was published in 1992, and Gladenkov has just produced a Russian translation of an abridged International Stratigraphic Guide. The Russian Code includes a few different concepts compared to the International, including a fundamental duality between principle stratigraphic units (global, regional to local rock formations) and special stratigraphic units (biostratigraphic, magnetic, cycle, etc.). These are associated with two levels of investigation – methodological and technological. A proper understanding of natural processes must incorporate a hierarchy from infra-zonal subdivisions to regional chronostratigraphic units.

c. Miscellaneous Stratigraphic Classification Items

(1) Rock versus Time nomenclature for Middle

We have Upper vs Late and Lower vs Early distinctions for rock versus the equivalent time divisions of the geological scale, but 'Middle' is currently used ambiguously. Peter Rawson presented a proposal from the British Stratigraphic Procedures publication that recommends '**Mid'** to distinguish the time-based unit from the equivalent rock-based 'Middle' in chronostratigraphy.

(2) Geochronometry standards

For absolute ages, the nomenclature abbreviations are standardized as 'Ma' and 'ka'. However, for intervals, there are no standard abbreviations and different journals have diverse

usages. It is recommended that '**myr'** and '**kyr'** be formally accepted as the standard abbreviations for elapsed years.

(3) Holostratigraphy

Peter Rawson suggested that the term 'integrated stratigraphy' for a suite of combined stratigraphic tools applied to a section is ambiguous. The term 'Holostratigraphy' ('holo' means 'all') may be more appropriate.

(4) Cainozoic

A long-standing error has been use of 'Cenozoic' (translating as 'empty life') as a mis-spelling of the original 'Cainozoic' (translating as 'recent life'). However, this usage may be too much ingrained into English-language journals and geological surveys to modify.

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4. Promoting Completion and Publicity of New GSSPs

- Strong Leadership. Both at the Subcommission and Task Group level. Push all the time. Have as the top agenda item.
- Regular Meetings. Not just discussions at the 4-year symposia to hear reports. Annual meeting of the Subcommission Chair with task group leaders.
- Regular Communication. E-mail and website. The Ordovician has an ongoing web-based discussion of certain potential GSSP placements.
- ICS provides seed money. Especially for essential fieldwork. The Subcommission must ask ICS in advance (budget year) for major amounts, but small contingency funds (few hundred dollars) are held in reserve.
- Subcommissions should link to the GeoSite program (IUGS). All GSSP sites should be on their list.
- Send GSSP write-ups to other newsletters, not just the formal *Episodes* publication.

FUTURE DIRECTIONS
Summary of Working Group Presentations and Discussions

1. New Missions and Goals for ICS

ICS Mission

The Commission is the primary body for facilitation of international communication and scientific cooperation in stratigraphy, defined in the broad sense of multidisciplinary activities directed towards better understanding of Earth history.

The ICS needs to excite the next generation with new tools, high-resolution event correlation on a global scale, and other projects with relevance to public concerns and imagination.

ICS Goals – develop a common language, then achieving global understanding of Earth's history.

(1) **Standards** – the major role under the mandates from IUGS. The ICS is responsible for standardization of stratigraphic concepts and the continued improvement of resolution of the International Geological Time Scale. Stratigraphy has evolving methods that will require new standards and provide progressively more depth in regional to global correlation. The chronostratigraphy time scale does not stop with just stage-level GSSPs.

(2) **Understanding** -- establishment of international frameworks and symposia for collaboration in understanding the evolution of the Earth. Most stratigraphers have focused interests, hence more involvement with subcommission-level activities than with the full ICS. The subcommissions and their sponsored symposia are valuable hubs for assembling specialists in intervals of geologic time (e.g., Jurassic, Silurian). In a similar vein, the ICS can provide international networks for thematic studies that require precise stratigraphic correlation (e.g., paleoclimate, tectonics, glacial episodes, eustatic sea-level).

Other scientific goals mentioned by the working group:

Absolute ages. The ICS could encourage radiometric age acquisition in key intervals that lack dates. For example, the early spreading history of the global oceans during the late Jurassic and early Cretaceous is poorly constrained (a 30 million-year gap in radiometric ages). It is important that the ICS reference time scale charts have reliable ages! This will partly be addressed by the ICS-sponsored task group to assemble a radiometric age database and associated decay constants (Villeneuve of the Canada Geological Survey, Palfy in Hungary, etc.), but IGCP-type attacks are needed to fill the age gaps.

Ecostratigraphy. The concepts of marine macrofossil ecostratigraphy should be extended to a wide variety of fossil groups and ecosystems. [*Note – the working group did not agree on a concise definition of 'ecostratigraphy'.]*

Integrated stratigraphy standards. The subcommissions should produce reference material on (1) the most reliable index fossils in all environments, (2) summaries of different regional stratigraphies and how these correlate to the global standard chronostratigraphy, and (3) inter-calibrations of different faunal groups and isotope-magnetic-sequence variations. An ICS goal would be a comprehensive book in 2008 that summarizes all regional to global stratigraphic scales including an absolute-time calibration.

Origin of Life. The ICS should sponsor investigations on origins of life, evolutionary jumps, rates of major leaps, and significance of rare fossil deposits (e.g., Burgess Shale). How do different ecosystems and geologic processes (e.g., weathering, biogeochemical cycling) respond to climatic and evolutionary changes in different settings (e.g., Arctic, tropical, bathyal)?

Units, not just lines. GSSPs focus on boundary events, but what happens within these units is also important. The ICS should encourage good 'interval' methods in stratigraphy, such as integration of radiometrics with cycle stratigraphy. How fast do things happen?

Caution on cosmetics:

An old dog with a new collar is still an old dog. The ICS must avoid merely changing terminology for objectives, but actively pursue new creative lines of global stratigraphy.

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2. CHRONOS – Earth History Database Concept, *under ICS scientific auspices*

Report by Jim Ogg on NSF-sponsored workshop.

Complete details and links are given on the CHRONOS website – ***www.eas.purdue.edu/chronos/***

CHRONOS Mission – to produce a dynamic, global timescale to frame Earth history events and processes for societal benefit.

A major direction of geoscience in the 21st century is the improvement and extension of facilities to collect and analyze data on local, regional and global spatial scales and appropriate temporal scales in which massive data archiving and distribution systems, both hardware and software, are required to provide access to geodata. (from *NSF Geosciences Beyond 2001*). A group of 30 international stratigraphers and information-technology specialists that represented the spectrum from paleontology to cycle stratigraphy to paleomagnetism assembled at Amherst, Massachusetts in Nov 2001 to prepare a plan for a comprehensive suite of global databases of Earth history, which they named CHRONOS.

The principle goals of the resulting CHRONOS initiative are:

- Assembly, integration and distribution of data relevant to geologic time
- Maintenance of a consensus geological timescale
- Public outreach – *Communicate to the public the importance of understanding rates in natural processes using the geological timescale*
- Research outreach – *Provide a fundamental research tool for the broader geoscience community and a temporal framework for understanding the 4th dimension (rates and processes)*

A chronostratigraphic database system is vital for future earth science studies in a vast spectrum of topics, including evolution and controls on biodiversity, catastrophes and abrupt climate change, climate history and oscillations, basin modeling, rate studies, high-resolution geochronometry, linkages of Earth's systems, and forward projection in future scenarios.

The suite of CHRONOS databases includes all chronostratigraphic data that have adequate attribution, including:

- Life – *paleontological assemblages, evolution, biodiversity, ...*
- Climate – *orbital forcing, oxygen isotopes, ecosystem changes, ...*
- Surface processes – *biogeochemical cycle monitors, strontium isotopes, ...*
- Care-Mantle dynamics – *magnetic reversals and intensity trends, plate motions ...*
- Catastrophic episodes – *impact-related anomalies, oceanic anoxia episodes, ...*
- Time – *absolute ages and relative ages, stage boundaries, ...*

A Standard Geological Time Scale is the centerpiece of the CHRONOS database system. The scale is linked to geochronologic and biostratigraphic scales, and is based on the highest quality data. A CHRONOS function is to continuously improve precision and accuracy of this Standard Time Scale according to international consensus and updating. Probably the scale will only have 5-year updates in order to maintain a reference standard. The scale will be transparent, in that the foundation data and methods of interpolating ages are clearly presented. CHRONOS provides the capability to link outcrop observations to the Standard Time Scale with error bars on the correlations.

The CHRONOS system will have thematic nodes (e.g., micropaleo, isotopes, radiometrics), each with distributed institutional databases housing the raw data, that are coordinated through a central global hub. The central hub will be responsible for the Standard Geological Time Scale, developing search and toolbox functions, and setting standards for databases. Examples of component databases include the Amoco-EGI dataset (19,000 sites, including 2000 research sections), the DSDP-ODP dataset (plus the Neptune compilation of all Cenozoic material and the Ocean Drilling Stratigraphic Network developed in Bremen), the North American Mammal Paleofaunal Database, etc. Some capabilities of the CHRONOS network include chronologic, geographic or thematic interfaces, transparent linkage to the Tapestry of Time public education network, personal user workspace to analyze and visualize assembled data, search engines with fuzzy logic and conceptual aspects, and different layers of interpreted to completely raw data.

CHRONOS will be under the scientific auspices of the International Commission on Stratigraphy, with an administration and multi-national funding structure similar to the international Ocean Drilling Program. A small permanent core staff of both information-technology and professional chronostratigraphers will be responsible for system standards, and international steering committees (academic, government, industrial members) will be responsible for oversight, planning and finances. The initial CHRONOS steering committee assigned to guide the CHRONOS initiative through early funding and development stages consists of ICS officers (Felix Gradstein, Rich Lane, Jim Ogg), public institutions (Brian Huber at Smithsonian), academic (Charles Marshall, Jim Ogg), government surveys (Bruce Wardlaw), industry (Jeff Stein, Paul Sikora), and public education (Cinzia Cervato).

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3. ICS Organization, Publicity and Funding

a. Subcommission Structure

ICS's stratigraphic-oriented structure (e.g., Cretaceous, Permian) would be retained, but thematic skill groups (e.g., biostratigraphy, geochemistry, tectonics) will be added that span multiple time intervals. Thus, ICS could act as a broker that matches skill groups with time-based projects to

examine exciting topics in stratigraphy. Some multi-discipline topics are Glaciation episodes, continental-oceanic effects of Milankovitch climate oscillations, Snowball Earth, geochemical cycles, biodiversity responses, and environmental and ecological problems.

The working group recommended that the Quaternary should be recognized as a subcommission that is subject to ICS statutes. However, the purpose of such an ICS subcommission (distinct from the encompassing Neogene system) and the relationship/overlap to the active INQUA program of Quaternary research was uncertain.

b. Meetings of the Full ICS Membership

The combined ICS membership (all chairs of subcommissions and the ICS Executive) should meet every two years, with open meetings at the quad-annual International Geological Congress alternating with intensive ICS-only meetings. Tentatively, an ICS meeting would be hosted during 2006 in Vienna (invited by Werner Janoschek, IUGS Secretary General). The alternating ICS-only meetings could also be designed to coincide near dates of other international stratigraphic meetings.

c. Publicity

ICS should interact more with other organizations, including other IUGS commissions (GEOINFO, etc.), INQUA, national stratigraphic committees, and national surveys. This will help to give ICS a more public profile.

ICS should publicize its accomplishments more aggressively, thereby increasing visibility and funding possibilities. Press releases, such as the significance of new GSSPs, needs to be distributed to all geological journals. At present, GSSPs are only published in *Episodes*, which has a restricted circulation (3500 copies) that is distributed to representatives of member nations according to a membership-support formula. In some nations, these copies never reach institutional libraries. Even in Europe and North America, most stratigraphers do not know about the existence of this journal. IUGS recognizes this problem and is trying to improve *Episodes* visibility and quality of articles with a review board. But, regardless, a single outlet is inadequate – ICS accomplishments should be published in *GSA Today*, *AAPG Explorer*, and other national geological newsletters.

Such publicity tasks and comprehensive web-information updating require a paid Secretariat (such as exists for IUGS central office), rather than only volunteers. IUGS has a task group on public affairs, but cannot provide ICS with funding for secretarial support.

d. Support – People and Funding

An expansion of ICS activities requires two ingredients – dedicated people, and funding. Employing full-time professionals (such as the Stratigraphic Information Services effort) is expensive, but perhaps a source of superbly qualified personal could be retired stratigraphers who still wish to contribute to a global understanding of Earth history and education in stratigraphy. With funding to cover expenses and travel, many retired professionals might be willing to devote their time and expertise toward ICS-sponsored activities. Other sources of dedicated short-term support could be sabbatical support for professors, and rotating internships for dynamic graduate students and post-docs.

ICS should move aggressively to pursue national, federal and industrial funds. Private philanthropy donations, which support many scientific, educational and museum activities in the United States, are generally discouraged under the tax policies of European and other countries, but could still be an important source. Component activities, such as the CHRONOS database network and stratigraphy-education modules, will have better access to specialized funding than will the

general ICS organization. Corporate funding is generally possible for activities that will benefit those industries (e.g., petroleum stratigraphy).

The ICS should promote more funding possibilities by marketing materials, such as general-audience or middle-school books ('Building the Time Scale'), stratigraphic journals (*see below*), printed glossy timescale posters, and short courses. Marketing educational modules in stratigraphic topics was discussed, but these are difficult to compile at an *inter*-nation level due to different educational standards. It may be preferable to allow downloading of educational resources from the ICS website (e.g., educational material) for free, and charge if printed versions are requested.

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4. Distribution of Standards

The ICS needs to be recognized as the authority for stratigraphic standards and as a premier source of high-quality stratigraphic information. Such information should be distributed freely on-line and printed copies provided to qualified stratigraphic institutions.

a. **International Stratigraphic Chart** (*name, rank, definition of units*)

'Presumably, the **Chart** should be mandatory for all geological projects run on an international basis with the financing and scientific guidance of the international organizations. Since in some countries, their own geological traditions are strong and justified by practice, the **Chart** is recommendatory for national and international projects and publications, provided the latter do not involve international geological organizations.' *(proposed by Russian Stratigraphic Commission)*

- Florence, 2004 – distribute copies of the Chart free to all delegates and present in IUGS and IGC Councils as the standard. Continuously communicate the evolving standard to the World Map group.
- Florence, 2004 – also include the Chart in all registration packets to attendees through IGC. We would request IGC to reimburse ICS for part of the printing costs, plus an extra Euro for ICS budget support.
- Distribute the Chart to all geological surveys as each GSSP and associated stage nomenclature is ratified. Follow up with direct person-to-person voice contacts to ensure that each survey understands the standard and the process that was involved.
- Distribute the Chart and periodic updates to all major geological journals and publishing houses. As with geological surveys, a follow-up call should be made.
- Publish Chart and links to get the PDF version from the ICS website in numerous newsletters – Easy and redundant access for all geologists and the general public.
- Codify the color information (CGMW = World Map, and the 'USGS' with our modifications). The USGS will adopt the Chart and associated 'USGS colors' as the official North American standard.

b. **Global and Regional Correlations**

- Each Subcommission should publish how regional stages and integrated stratigraphies 'map' into the International Scale for each system. Distribute these important 'user-friendly' guides by web-posting, widespread publication in newsletters and journals, delivering to geological surveys, etc.
- Each Subcommission is encouraged to compile a summary volume, similar to the

'Carboniferous of the World', perhaps keeping these continuously updated as a web posting.

- *Next level* – Subcommissions should post most commonly used zonal schemes (*with images of key zonal markers*) and integrated stratigraphic scale (*with uncertainties in inter-calibration*).

c. **Lexicons** (definition of lithostratigraphic units)

ICS web site should have links to lexicons of countries. Belgium has complete lexicon (but not on-line), Italy is in middle of extensive on-line series (very labor-intensive, with a dedicated Maria Bianca Cita), USGS has basic information on-line, etc.

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5. Publications

At present, the ICS and the subcommissions have a limited amount of information on-line. Only the Triassic Subcommission, with the *Albertiana* journal/newsletter, has any presence in a few libraries, and symposia proceedings periodically appear in special journal issues or monographs.

The *Computers in Geoscience* journal of the Internet. Assoc. Mathematical Geology provides an overabundance of funds for that association, plus a high-profile visibility. We could adopt an existing journal (e.g., something like *Newsletter of Stratigraphy*) for a printed professional presence in libraries and/or begin a new one (maybe using the Chronos name, similar to the database initiative) via electronic, cyberspace means.

a. Printed Professional Journals and Monographs

Young people want to publish in journals with a high-ranking citation index profile. This takes time to develop a circulation and quality standing, and is a problem when beginning a new journal (or acquiring one that doesn't have a good track record).

The Quaternary Research Association (UK) began a Quaternary journal with a contract to Wiley Publ. The Publisher does not own the journal, the organization does with a certain amount of income (after an initial return to the publisher) going to the organization. With a current 500 circulation, the profit in 2001 was 10,000 pounds back to the organization.

Unfortunately, the scientific journal market is over-saturated. Libraries are generally trimming on buying journals, rather than adding new ones.

Most subcommissions contract with publishers for their special issues or symposia volumes, with no return percentage to the organization. It may be preferable to farm out special books for printing and distribution by the Geological Society publishing house, which charges less than commercial.

Sorin Filipescu and Simone Galleotti will explore further investigation of publication costs, in-house printing, and journal options.

b. Electronic Journals

Electronic publication, such as the Geochemistry, Geophysics, Geosystems (G3) journal (http://146.201.254.53/), is now desired – low costs, continuous production rather than waiting for enough articles to fill the issue, color and animated graphics, 4-dimensional models, and other features. The downside is being invisible in libraries (but this is rapidly changing)

c. Printed Popular Journals

For many years, a consortium of U.S.A. oceanographic institutions on the Atlantic coast produced an oceanography journal, OCEANUS. Each issue was centered on a theme, such as bioluminescence, submersibles, hydrothermal vents, etc. A dedicated editor was largely responsible for the success of this educational journal, which was received by numerous schools and professionals.

A similar theme-oriented quarterly journal in stratigraphy might have a wide appeal. Certainly there is no competition in this niche. Beautiful front-page covers, full color images, general-geology level of review articles, and directed toward understanding new stratigraphic concepts and events. Possible issues could include end-Permian mass extinction, Snowball Earth, past impacts, evolutionary trends, history during the Cambrian (or other periods), anoxic ocean events, sequence stratigraphy, and cyclic sedimentation applications in time scale. An electronic edition could also be prepared.

d. Printed Color Timescales

ICS could send nice-quality color prints (11x17 inch, or poster-size) of the International Stratigraphic Chart, a standard timescale (absolute ages), regional correlation charts, and other products. These items would always be free to download (PDF files) from the website, but requests for printed versions could be handled by a credit-card order through the website, with mailing in tubes from American, Europe or Asian sites as appropriate. Such an on-line and mailing system would require ICS having credit-card processing approval, plus one or two regional people to do the mailings (unless this is subcontracted).

The IUGS-UNESCO printing of the Chart in 2000 was assigned an ISBN number, hence can be cited in publications. However, a web-updated chart that incorporates changes every 6 months would require adding new ISBNs or some 'edition' reference.

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6. International Stratigraphy Awards

There is no international award for achievements in stratigraphy.

Felix Gradstein proposed an international prize for the greatest contribution to stratigraphy. This concept was refined during discussions into two prizes – the HEDBERG for outstanding academic lifetime achievements or major revisions in the way that we understand the Earth's stratigraphy (e.g., to Oppel for the zonal biostratigraphic concept and applications to Jurassic correlation), and the STENO for the best young stratigrapher (under 33 for a major paper and discovery). The STENO would be the most difficult decide, because it would have to rely on national nominations of young geologists, language differences (we wish to avoid a bias toward publication in English-language Anglo-European journals), and evaluation of 'achievement' at an early stage in one's career.

A committee (Morton, Rong, Finney) will formulate a plan for these awards and associated presentations, with the first set of prizes to be given at the Florence 2004 IGC. A committee would be needed to solicit nominations and make a selection. A possible prize amount is travel to the IGC.

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7. GSSP Plaque

Richard Lane presented a template for a standard marker for GSSPs. In addition to providing the basic information (placement in stratigraphic scale, meter level and primary correlation criteria), the plaque would include an estimate of the absolute age, and be produce in the local and English language.

The local governments would be encourage to supplement this simple field plaque with explanatory signs, such as the dual set at Massignano base-Miocene GSSP (stratigraphy methods, importance of the GSSP). Information for such signs at an education-public level would need to be provided by the associated subcommissions. The Portuguese have produced a CD-ROM documenting their base-Aalenian GSSP in both languages.

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8. Next Step – ICS at Florence 2004 IGC

The new directions for ICS will be presented at a special workshop at the Florence 2004 IGC. Prior to this open assembly, each subcommission should hold an afternoon business meeting, to which at least one ICS Executive officer should also attend. If three or four subcommissions meet daily, then all will be completed during the first five days of IGC. These subcommission meetings will be followed by an ICS-chairs-only business meeting (day 7?) to get progress on the GSSPs and other issues.

The ICS should consider a permanent booth (with copies of charts, etc.) in the GeoExpo arena to provide information and improved visibility.

ICS open workshop is planned as a follow-up to Urbino, with a 3-hour session hosting up to 75 people being authorized by IGC (day 9?). The ICS should probably budget for refreshments to encourage attendance. Following this general meeting, the ICS executive will meet to review and summarize the issues and achievements.

This general workshop, plus the chairs-only meeting, will provide the basis for the post-2004 strategic plan of ICS.

First Conference on Future Directions in Stratigraphy, 14-16th June 2002
Campus Scientifico dell' Università, Urbino, Italy

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